

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during February, 1931—Continued*

FEBRUARY 28, 1931

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt 100 m.	Humidity		Wind		Remarks
					Relative	Vapor pressure	Direction	Velocity	
P. m.	M.	Mb.	°C.		%	Mb.	n.	M.p.s.	
4:19	225	988.5	5.8		89	8.21	n.	7.2	10 A. St., WSW.
4:19½	469	958.9	4.2	0.66	93	7.67	nne.	8.8	
	500	955.0	4.5		91	7.66	nne.	8.8	Clouds thinning
4:20	581	946.2	6.4	-1.96	83	8.46	nne.	8.6	overhead during
4:21	745	929.2	7.6	-0.73	78	8.14	ne.	8.3	flight.
4:22	949	904.0	7.2	0.20	67	6.81	ne.	3.7	
	1,000	900.0	7.0		66	6.61	ne.	3.0	
4:23	1,255	871.7	5.2	0.65	60	5.30	ne.	3.0	
	1,500	844.0	3.3		66	5.11	ne.	3.4	
	2,000	796.0	-0.9		80	4.54	ene.	4.1	
4:29	2,397	755.4	-4.0	0.81	90	3.95	ne.	4.3	
	2,500	746.0	-3.9		78	3.45	ene.	3.6	
4:30	2,530	743.3	-3.8	-0.15	70	3.12	ene.	3.5	
	3,000	700.0	-7.0		77	2.62	ne.	6.0	
4:33	3,335	672.5	-9.0	0.65	81	2.32	nne.	3.5	
4:33½	3,478	667.6	-9.8	0.56	81	2.16	n.	3.0	
4:34	3,560	648.8	-11.0	1.46	70	1.68	n.	3.1	

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					Relative	Vapor pressure	Direction	Velocity	
P. m.	M.	Mb.	°C.		%	Mb.	n.	M.p.s.	
4:35	3,764	631.7	-10.4	-0.29	60	1.52	nnw.	3.7	
	4,000	614.0	-12.4		62	1.31	nnw.	3.5	
4:40	4,529	571.3	-17.0	0.86	67	0.93	nnw.	4.2	
4:42	4,896	546.6	-19.2	0.60	63	0.71	wnw.	3.4	
	5,000	539.0	-19.0		62	0.71	w.	3.6	
4:43	5,090	531.6	-18.4	-0.41	61	0.74	wsu.	3.7	
4:47	5,865	477.1	-25.4	0.90	64	0.39	wsu.	4.2	
	6,000	470.0	-25.4		64	0.36	wsu.	4.6	
4:50	6,650	428.5	-30.3	0.62	69	0.26			
4:52	6,905	415.0	-30.7	0.16	70	0.25			
	7,000	409.0	-31.5		70	0.23			
	8,000	353.0	-40.6		70	0.08			
5:00	8,201	341.8	-42.4	0.90	70	0.07			
	9,000	302.0	-51.0		69	0.02			
	10,000	258.0	-61.3		66	0.01			
5:09	10,047	256.9	-61.8	1.05	66	0.01			

SERIOUS EROSION CAUSED BY HEAVY RAIN OF JULY 30, 1931, NEAR COLFAX, WASH.¹

By W. A. ROCKIE

On July 30, 1931, the weather conditions near Pullman, Wash., were such as would normally result in a severe thunder storm. A heavy cumulus cloud formed and hung to the west of town for several hours during the afternoon and evening. The storm cloud did not advance eastward toward Pullman as would normally be expected in this region but instead it expended its force and violence practically where it formed. There was but a trace of rain at Pullman; Lewiston had 0.02; Colfax had 0.21; Lacrosse had 0.14; Moscow had 0.06; but none of these points were in the area of the real rain. The real storm occurred over an area of about 50 square miles centering around the point where the Colfax-Almota road crosses Union Flat Creek. No severe rain occurred more than 5 miles from this point. This area is located about 10 miles west of the erosion station farm.

According to climatological data for the Washington section² precipitation was recorded on this date at 30 out of 105 stations listed in the Eastern Washington division (approximately eastern three-fifths of the State). The same publication of the Idaho section³ shows that rain occurred on the same day at 64 out of 103 stations in the State of Idaho. The wide extent and very generally rainy tendency on this date in both Washington and Idaho, even though the rains were generally of negligible amount, shows that conditions were very favorable for precipitation in all parts of the region. The records of both Washington and Idaho are shown because Pullman is only a few miles from the Idaho line.

On the following day the Spokane newspaper contained a very graphic account of a "cloud-burst" that occurred on the area mentioned. The newspaper accounts of this rain were all centered upon the damage to personal property and to physical improvements located in great part

downstream from the points where the heaviest rain fell. These reports were apparently very conservatively stated. In fact, they did not begin to tell the story of the damage that had actually occurred.

The several succeeding days were spent examining the area which had suffered from this rain storm. According to all information and evidence the heavy rain must have lasted only a very short period. Verbal accounts of the time of the rain itself differ considerably within the region affected. The only accurate record which we were able to obtain regarding the amount of rain which fell was obtained from Mr. W. P. Gilbert a farmer living just inside the limits of the area which showed evidence of the heavy rainfall. At his house, which was very close to the northeastern edge of the storm, 1.6 inches were recorded in 20 minutes, while on a more distant part of his farm 1 mile to the westward his measuring gage (a straight-sided can) actually caught 3 inches of water. He was at the house during the rain. While it is quite possible that more rain fell at some individual spots within the area than these records indicate we have not been able to secure any other figures. Mr. Gilbert has been keeping rainfall records at his farm in past years and we believe that his records are reliable.

The farm land within the area is typical of Palouse topography and is characterized by Palouse silt loam soil. It has fully as rough a topography as the average within the region, having many cultivated slopes in excess of 50 per cent gradient. The dominant farm crop rotation in the area is winter wheat and summer fallow. Some other crop conditions which were observed following the storm were spring wheat, alfalfa, bunch grass pasture, and fall wheat seeded in summer for summer pasture. A complete survey of the crop conditions was not attempted so other crops were also undoubtedly present.

The damage done to the land through erosion by this heavy rain was directly related to the vegetation which covered any given field on that date. The summer fallow land eroded to plow sole but did not generally go below that line. Individual fields containing several

¹ The writer wishes to express appreciation to P. C. McGrew, agricultural engineer in the Bureau of Agricultural Engineering, for the photographic illustrations which accompany this article. 1. Superintendent, Pacific Northwest Soil Erosion Experiment Station at Pullman, Wash.

² Climatological data, Washington section, U. S. Weather Bureau, Vol. XXXV, No. 7, p. 53.

³ Climatological data, Idaho section, U. S. Weather Bureau, Vol. XXXIV, No. 7, p. 33.



FIGURE 1.—Erosion from rain of July 30, 1931. Upper slope is fallow and lower slope is winter wheat planted late (probably about June 1) for summer pasture. This wheat was pastured close and is only 1 to 2 inches high but the root growth was very effective in stopping erosion. Location: SE. $\frac{1}{4}$ sec. 7, T. 15 N., R. 43 E., Whitman County, Wash. August 1, 1931. (Photo by P. C. McGrew)



FIGURE 2.—Erosion on 40 per cent slope of field in summer-fallow from rain of July 30, 1931. Ditches go to plow pan and are 5 to 10 inches deep. Location: Holbrook farm, sec. 21, T. 15 N., R. 43 E., Whitman County, Wash. (Photo by P. C. McGrew)



FIGURE 3.—Erosion on 40 per cent slope of field in summer-fallow from rain of July 30, 1931. Ditches go to plow pan and are 5 to 10 inches deep. Location: Holbrook farm, sec. 21, T. 15 N., R. 43 E., Whitman County, Wash. August 1, 1931. (Photo by P. C. McGrew)

hundred acres unquestionably lost as much as 2 inches of soil from their entire acreage. This has been estimated to have a distributed loss as follows: 25 per cent of the area lost 6 inches or more of soil and the remaining 75 per cent lost from 1 to 6 inches. It is firmly believed by the writer that no summer fallow land lost less than 1 inch of soil during the storm. Individual tracts of 1 acre were found which had lost 6 inches or more of soil over 90 per cent of that acre. Individual areas of one-tenth acre each were found to have lost from 8 to 10 inches of soil from 100 per cent of their area. The individual rivulets and gullies dug down as far as the soil had ever been loosened. On the farms where deeper plowing had been practiced the soil losses were, therefore, probably greater. The washing of the soil in summer-fallowed areas was found to have started within 15 feet and, in some instances, less distance from the ridge top. It appeared certain, therefore, that 15 feet of watershed was sufficient to start washing practically to plow pan and this destructive action tended to increase downward toward the draws.

The individual gullies washed in this loose-plowed soil were generally from 3 inches to 1 foot in width but with the slightest tendency toward a union of two or three or more of these smaller gullies a much more destructive condition resulted which produced thousands of gullies within the area from 5 to 10 feet in width with the plow sole as the gully floor. The side walls of these individual gullies were for the most part as nearly vertical as loose moist Palouse silt loam will stand.

The marks of the plow at the plow sole were plainly evident in all of these flat bottomed gullies. Since most of the plowing in the region is done with the contour this usually caused the plow marks to be perpendicular to the direction of the gully but occasionally in flat basinlike areas at the foot of a steep slope these perfectly preserved marks of the plow on the heavy solid clay loam subsoil were very strikingly portrayed.

The wheat in some of the fields had just been harvested, while on others the ripe fall wheat or nearly ripe spring wheat was still standing. The same heavy rain falling on either stubble or standing ripe, or nearly ripe wheat, caused practically no damage. Occasionally sufficient surface water washed from a wheat field to form a definite channel on the slope knocking flat the wheat within that channel from its vertical position but in no instance was this stream found to have dug into the soil. Even this stream of water was the exception and on most of the wheat it appeared that the rain either went entirely into the ground or so much of it did so that there was not enough water run off to make rivulets of sufficient size to leave any evidence.

Several alfalfa fields were carefully examined and on none of them could the slightest evidence of soil washing be found. These alfalfa fields had new upright shoots of alfalfa which were usually less than 12 inches in height and rather scattering, since from July 1 up to the date of the rain the weather had been very dry. One field which had been seeded to alfalfa in the spring of this year had a rather sparse growth, and even this did not show any soil or water losses from the slopes.

Similarly, a portion of a field most of which had been left in summer fallow had been seeded in early summer to fall wheat for summer pasture. From the nipped

condition of all of this wheat pasture it was apparent that it had been pastured continuously during the entire summer period and practically no spears of the plants were as much as one inch above the ground surface. This pasture area occupied a draw and the lower half of the steep adjoining slopes. Above on both slopes was summer fallow. The summer fallow was completely riddled by thousands of shallow gashes but these gashes stopped exactly at the upper edge of the wheat pasture in all instances; there were no exceptions.

Certain areas were found where summer fallow occupied the head of a watershed, some totaling a very few acres, others hundreds of acres. On certain areas summer fallow was found to cover the ridges, with ripe wheat or some other crop on the lower slopes. In other instances this condition was reversed, thus giving a complete check on just what part each vegetative condition played in the control of this great amount of water dumped onto the land in a very short time. No matter what topographic position the summer fallow occupied, erosion began within a few feet of the upper edge or upper level of the summer fallow, and in like manner no matter what topographic position the vegetative cover occupied, evidence of erosion of the soil ceased upon entering any vegetative area.

The physical evidence of the speed with which the rain fell and the flood formed and flowed away is best illustrated by the following facts. From a 3-acre watershed of summer fallow a violent stream of mud about 40 feet wide laid flat a standing crop of wheat in the draw which drained these 3 acres. After the flood had passed numerous soil "bowlders" were found lodged all along this draw for as far as 1,500 feet from the summer fallow. These bowlders consisted of the rounded cores of huge clods of dry black surface soil from the summer fallow which had been picked up, dragged along the bottom of the flood for distances up to 1,500 feet, and worn into true rounded "bowlders." All these movements were accomplished before these "bowlders" had a chance to moisten, else they would have disintegrated to loose, mellow soil. Had they been of clay subsoil material, this would not necessarily be true, but with black Palouse silt loam, such "bowlders" could form only of dry, hard material.

It mattered not what that vegetation was, how steep the slope might be nor how much momentum the flood had been given by a long slope of summer fallow above, the erosion stopped when vegetation was encountered. Further than that all vegetation which had any appreciable height acted as a strainer or filter causing the silt, which was being carried in suspension by the run-off waters, to settle. The result of this was that wherever a flood of water from summer fallow went through any vegetative area there remained afterward a freshly deposited silt layer on top of the old soil surface. The depth of this layer naturally decreased as the distance from the summer fallow increased.

These observations all indicate one fact, namely, that vegetative growth is a most effective control of soil washing and of run-off moisture losses.

The individual characteristics of each vegetative type or plant are undoubtedly factors of importance in this regard, but no study was made of these details.